VHF DIRECTION FINDING

WITH A MINIATURIZED BEAM ANTENNA

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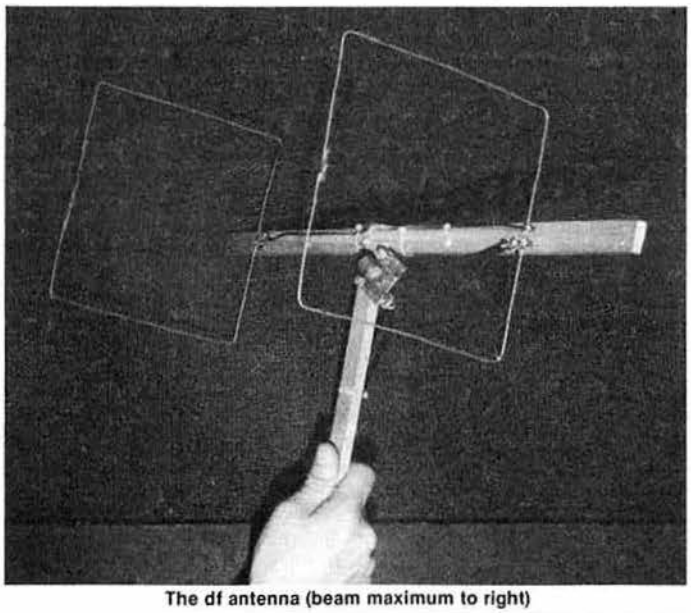
He took the RAE at the age of 14 and obtained amateur licence G8ITH in April 1974. His current amateur radio activities include automatic morse decoding and sending at ms speed for which he has written and tested programs on a Nascom 1 on 144MHz.

Introduction

VHF direction-finding enthusiasts on the 144MHz band often make use of a portable beam antenna which can be hand-held, typical examples being the HB9CV and the ZL-Special [1, 2, 3]. The basic principle is to hold up the antenna and rotate it until the direction of maximum signal strength, or the minimum off the back of the antenna, is determined with the aid of an S-meter.

To facilitate direction-finding where the size of an HB9CV type beam might be inconvenient, the df beam to be described has been developed, and works well in practice. It has a maximum dimension one third that of the HB9CV.



The df antenna (beam maximum to right)

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Theory

Of the many direction-finding techniques which exist, two methods are in general use. In the first, the antenna is rotated and the peaks or nulls in the signal strength are noted, while the second uses antennas spaced so that the phase differences of the received signals can be interpreted to give the direction of wave travel across the antenna system.

The second method is used by commercially-available antenna scanners with whips in a circle or square which give a bearing on an l.e.d. readout. This is also known as a doppler system because the electrical rotation of the antenna beam, by cyclic switching of the antennas, produces a phase shift which is equivalent to the modulation and doppler shift that would be the result of rotating the actual antenna array. These scanners are expensive and could be awkward to equip for use on foot, especially when the transmitter is sited on rough land.

In another method, two beam antennas have the beams angled apart so that the signal direction is off the side of each and in between the two beams, the signals from each beam then being of equal strength.

The method to be described is the simplest for home construction, but requires excellent screening of the receiver, and use of antenna attenuators to prevent the receiver being overloaded at close range. To get an unambiguous bearing, the antenna must have a unidirectional response pattern. Fig 1 shows two possible patterns. The cardioid is typical of hf loops with a vertical sense antenna, or of a two-element array spaced $\lambda/4$ apart. The antenna is rotated for minimum signal, and the null is sharpest with $\lambda/4$ spacing (maximum front to back ratio). Antenna nulls are usually sharper than the beams, so enabling accurate bearings to be read. A beam antenna can be used by adjusting for maximum strength on the beam,

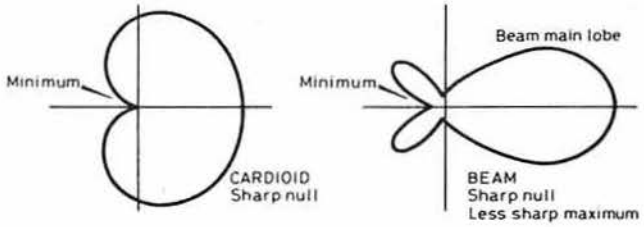
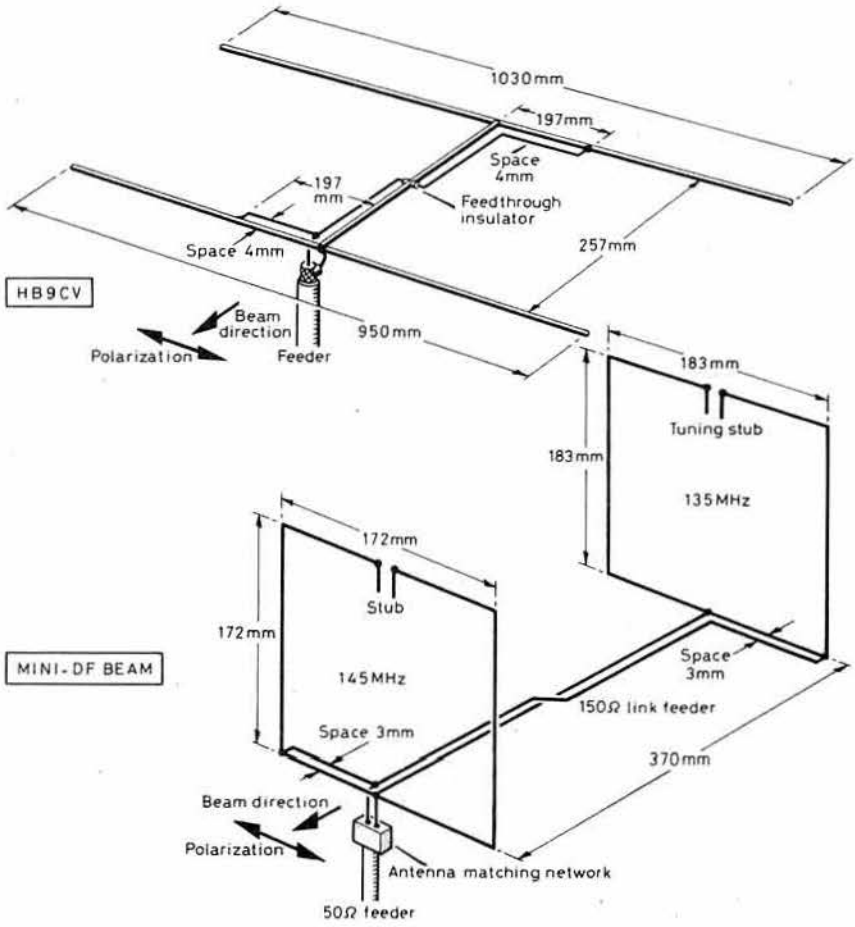
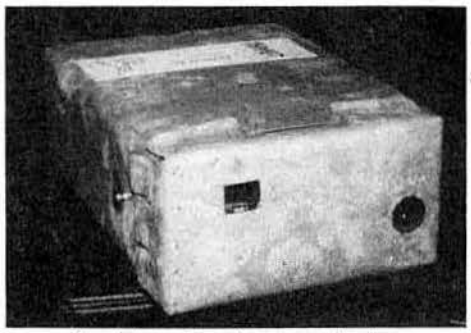


Fig 1. Antenna patterns for direction-finding





Front view of receiver screening box

Fig 2. Mini direction-finding antenna for vhf. A tuning capacitor (30pF trimmer) is normally connected in parallel at the feedpoint of the HB9CV (See *Radio Communication Handbook*, p14. 24)

or for a minimum on the null as for a cardioid. Beam antennas usually have less than λ/4 spacing, which worsens the front-to-back ratio and the sharpness of the null.

Construction of a mini df beam

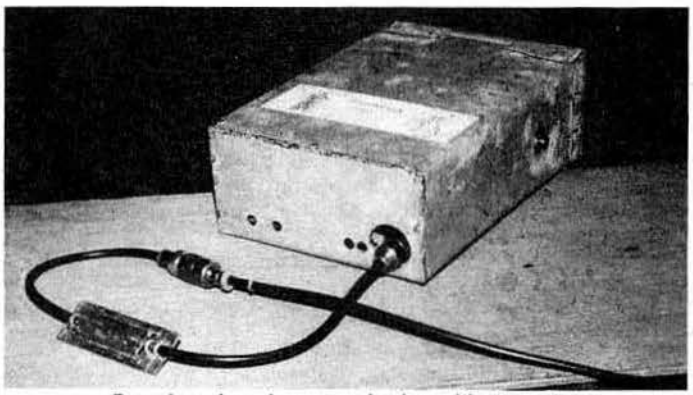
The configuration of a mini df beam for 144MHz is shown in Fig 2, and it can be seen to be somewhat similar to, but smaller than, the HB9CV, which is shown for comparison. This was the most successful arrangement found after much experimentation with small wire loops.

The antenna uses two small wire loops capacitance loaded and phased to get a unidirectional beam. The feed arrangement is the same type as that of the HB9CV, using gamma matching to each loop. The loops can be considered as the elements of an HB9CV shortened and bent into a 7 by 7in square, with the ends fixed to an insulator to which is attached a loading capacitor.

Dimensions for construction are given in Fig 2. The prototype was made from 16swg wire loops soldered to wood screws in the support. The loops are spaced at 70 per cent of λ/4 spacing, slightly more than the λ/8 of the HB9CV, as a compromise between narrow beam and maximum front-to-back ratio. The beam direction is parallel to the centres of the squares in the direction of the feeder-end loop, and there is a null in the opposite direction. The loading capacitors may be made from double-sided pcb, but these are difficult to adjust. A better way is to use an insulator made from glass-fibre pcb, with an insulating gap cut in the copper, and with a length of 75Ω twin feeder connected to it as a small capacitor. Initially, about 2in should be connected and trimmed by small amounts to tune the loops. If 75Ω twin is not available, 300Ω ribbon may be used, but a greater length will be needed.

The loops should first be tuned without any feeder connections at all. The radiator loop is tuned to 145MHz with a gdo,loosely coupled and away from objects. The reflector loop (fed by a reversed 150Ω link feeder) is tuned to within limits 135–137MHz. The link feeder and gamma match connections are then made. The gamma wires are 16swg spaced 3mm from the loop and tapped at the corner of the loop.

The link feeder is 150Ω characteristic impedance, made by paralleling two



Rear view of receiver screening box with attenuator

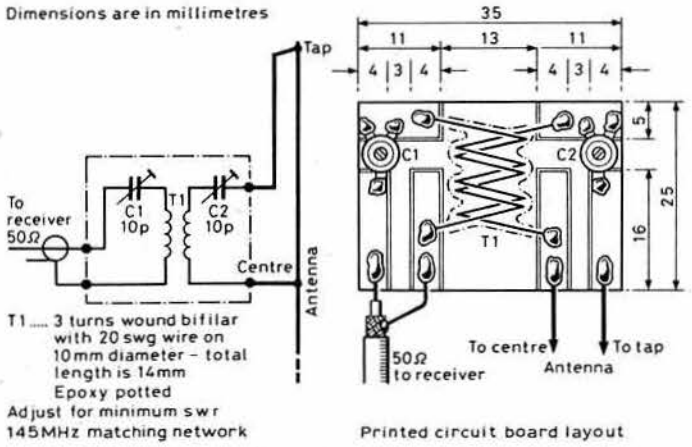


Fig 3. Antenna matching network

lengths of 300Ω ribbon and tying each conductor pair together by cutting holes in the insulation and putting nylon cable ties around them. The impedance is not critical, but better practical results with a well-defined beam pattern were obtained when an impedance between 75 and 300Ω was used, 150Ω giving the best results. This would affect the relative loop currents.

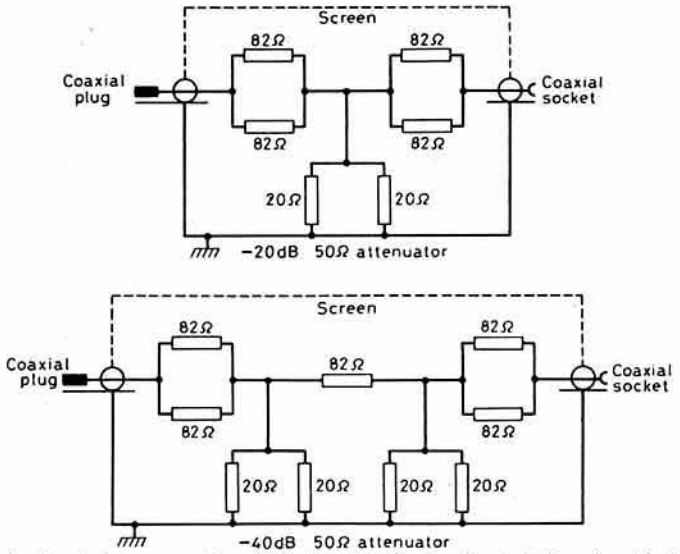
The feed loop is connected directly or, at most, through 5in of 75Ω twin, to a small antenna-matching network built on a piece of pcb. This network is necessary as the impedance of the folded loops is low, and a balun action provided by a bifilar transformer helps prevent the polar diagram being upset by rf picked up on the coaxial feeder. The matching network, which will also tune other homebrew antennas, is detailed in Fig 3.

In the prototype the 50Ω coaxial cable connected to the matching board was 182cm long, and, to further prevent rf on the coaxial outer affecting the antenna pattern or the receiver, two small ferrite rings were slipped over the coaxial cable at each end and secured. A mounting frame with a handle to support the loops was made from two pieces of 1 by 0·5in wood in a T-shape, varnished with polyurethane.

Having made the antenna, there are two more items necessary for the prospective df hunter. When the transmitter has been traced to within a few hundred yards or so, depending on its power, it will saturate the receiver and give a full-scale S-meter reading whatever the antenna direction. A null reading direction will reduce the input by several decibels, but to retain useful signal strength readings it is necessary to attenuate the rf before the receiver antenna socket. The circuits of 20dB and 40dB ladder attenuators are given in Fig 4. As the attenuators are only intended for receiving, small wattage standard resistors may be used. Commercial attenuators could be used of course, but will cost a lot more. The attenuators are constructed on a copper pcb sheet 3 by 1in as in-line units with PL259 line plugs and sockets. Short connecting lengths of coaxial cable from the plugs are secured to the pcb with cable ties. The attenuators must be well screened, and a tinplate screen can be soldered down over the resistors, leaving just enough space for the coaxial leads. Used singly or both in line, attenuation of 20, 40, or 60dB is possible and necessary.

Finally, even with a dummy load or no antenna the receiver is likely to be swamped within close range of an unseen transmitter, as the screening of most receivers is inadequate for this type of df work—the only solution is to screen the entire receiver. The author found that a local 250mW transmitter transmission could break through a metal biscuit tin with a closed lid, fully quieting the FT290 inside.

To get reasonable protection from breakthrough, a sheet metal box can be made from tinplated steel soldered along each seam. (Welded boxes would be suitable if continuous welds rather than spot welds were used). A lid with contact fingers all round completes the screen. Minimum-size holes are cut for the antenna lead, the S-meter viewing, and the strap lugs of the FT290, (which may be extended with washers). Small holes are cut to get at the back switches of the FT290 via a screwdriver. The prototype box reduced breakthrough from 25W at 15ft to S7-9, compared with S-meter full scale deflection without the box.



Use low inductance resistors (not wire-wound) and cut leads to 5mm for vhf use

Fig 4. In-line attenuators of constant impedance. Cascade both attenuators for −60dB

Using the df equipment and field trials

Tracking down a hidden transmitter consists of measuring the bearing of the signal, knowing the direction of the maximum and minimum response of the antenna. The bearing can be followed and used in conjunction with previous readings to get a map cross-reference. A map and compass are very useful items.

With some experience, the signal strength is another useful guide. At the start of the hunt, signals may be relatively weak, so that rotating the antenna for maximum signal strength is most useful, but the null direction will be more useful as the station gets nearer and the signal gets stronger. When very close to the hidden transmitter, the signals may be so strong that only the S-meter dip due to the null can be seen, and you may also need 60dB of attenuation.

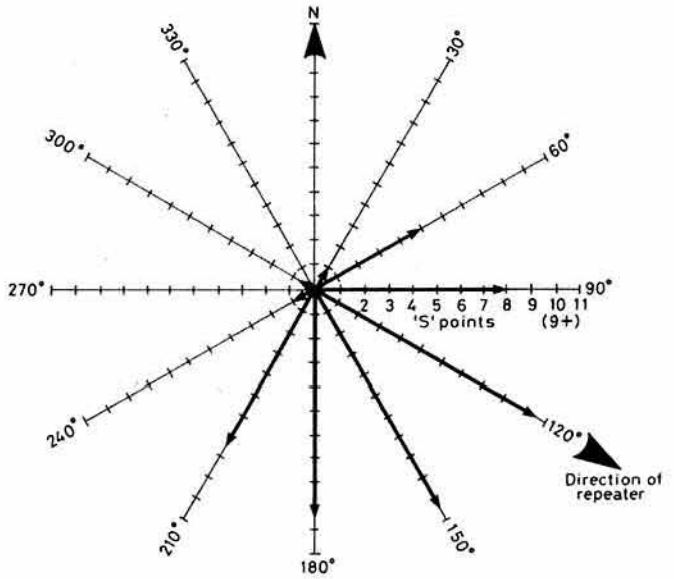


Fig 5. Dual mini df loop H-plane S-meter response (FT290R) measured indoors

This mini df beam antenna can easily be used vertically or horizontally polarized, and was constructed primarily as a vertical beam to correspond with the more frequently expected vertical hidden antenna. As you get nearer the transmitter, signals will begin to saturate the S-meter, so attenuators sufficient to stop the meter from overloading must be inserted.

With high attenuation in circuit, it is possible to lose the signal and not notice if the transmitter operates with a call every few minutes intermittently. Equipment such as the FT290 has its own antenna, which can be extended for monitoring, or an assistant with another receiver can monitor.

Conclusions

It is hoped that this description of a compact df beam antenna which is easier to handle than the HB9CV, will encourage df activity on the vhf bands for df hunts of all kinds.

Experience with the use of the mini df beam suggests that the H-plane polar response (antenna rotated horizontally while held vertically polarized) is "sharper" than the E-plane response, and is also better defined in the presence of nearby objects (eg indoors).

Fig 5 shows the S-meter readings to be expected when the beam is rotated while vertically polarized and receiving a transmission. The experiment was performed indoors using the author's FT290. Generally speaking, best polar responses occur in the open air with the polarization of the antenna matched to the transmission, and the construction of this antenna can make it easy to alter the polarization.

As a transmitting antenna, the df mini beam performs about as well as a dipole, and also makes a convenient pushbike mobile antenna.

References

[1] *Radio REF* March 1981, pp 155-71.

[2] "Technical Topics", *Rad Com* October 1981.

[3] *Radio Communication Handbook*, 5th edn, p14. 24.